

Looking Inside the Third Generation Left Ventricular Assist Device Using Color Doppler Transesophageal Echocardiography

Abstract

HeartWare is a third-generation continuous flow left ventricular assist device (LVAD) and generates centrifugal pattern of blood flow. In the perioperative setting, interrogating the HeartWare devices is very difficult due to the interference of the Doppler by the impeller frequency and generation of the waterfall artifact. We present a case where using color Doppler a view “inside” the impeller can be seen which corresponds to the centrifugal flow of blood. With time, these images can be looked into in pathological states such as pump thrombosis, to come to a more meaningful conclusion regarding the flow of blood within the centrifugal chamber. Newer technologies are constantly evolving to give us more meaningful insights into the flow of blood within the heart chambers. We believe similar technologies can be applied to see the flow of blood inside the LVAD devices.

Keywords: Color Doppler; heartware, left ventricular assist device, transesophageal echocardiography

A 68-year-old female with a history of nonischemic cardiomyopathy due to rheumatic heart disease s/p mitral valve replacement, tricuspid annuloplasty, and biventricular pacemaker implantable cardioverter defibrillator who was on home dobutamine presented with increasing shortness of breath. Her worsening heart failure led to a planned third generation left HeartWare (HeartWare International, Framingham, MA) ventricular assist device (HVAD) implantation as a bridge to transplantation in the operating room.

Intraoperative transesophageal echocardiography (TEE) imaging using the Philips iE33 machine (Philips, Andover, MA, USA) showed an ejection fraction (EF) of 10%–15% with severe global hypokinesis of the left ventricle, bioprosthetic mitral valve with trace mitral regurgitation, tricuspid annuloplasty with mild right ventricular dysfunction. Two-dimensional TEE post-cardiopulmonary bypass and after HVAD implantation showed a normal apical positioning of the inflow cannula in the mid-esophageal four-chamber view [Figure 1]. Velocity profile of the inflow cannula could not be determined due to the “waterfall artifact” which is often seen when the inflow cannula is part of the

imaging sector.^[1] The outflow cannula was visualized in mid-esophageal ascending aorta long axis view with flow confirmed using color flow Doppler [Figure 2]. The spectral velocity pattern in an outflow cannula can also be seen showing characteristic systolic peak and diastolic nadir [Figure 3].

When the inflow cannula at the left ventricular apex was evaluated in mid-esophageal four-chamber view with color, a distinct vortical color flow pattern can be seen from mitral valve to the inflow cannula. On further examination, a centrifugal color flow pattern can be seen from the inflow cannula apex, diverging outward to take the shape of the HVAD flow chamber, consistent with the centrifugal blood flow within a HVAD device [Figure 4]. The color flow Doppler aliasing velocity was not adjusted with respect to the baseline or scale to obtain these images. However, the aliasing velocities were in the range of 25–30 cm/s due to the large color Doppler window. Video 1 shows a vortical pattern as it evolves during the cardiac cycle from mitral inflow to the inflow cannula and ultimately taking the shape of the centrifugal chamber of the HVAD. Video 2 shows a three-dimensional image with the color flow of the similar pattern. As blood

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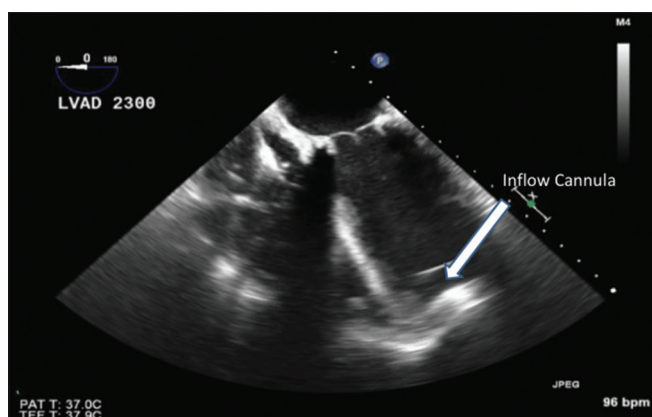


Figure 1: Mid-esophageal-four-chamber view with inflow cannula of HeartWare device (white arrow)

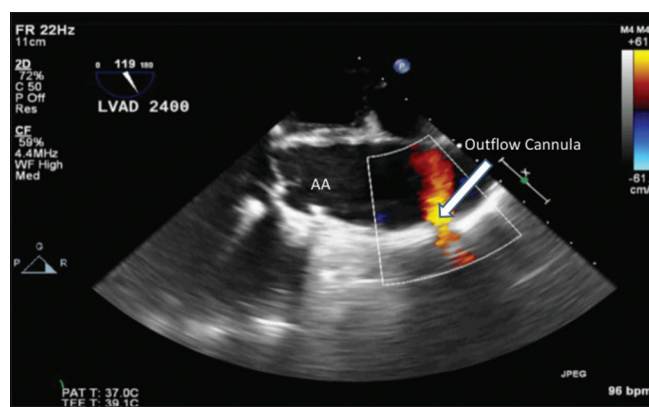


Figure 2: Mid-esophageal ascending aorta long-axis view with outflow cannula of HeartWare device (white arrow)

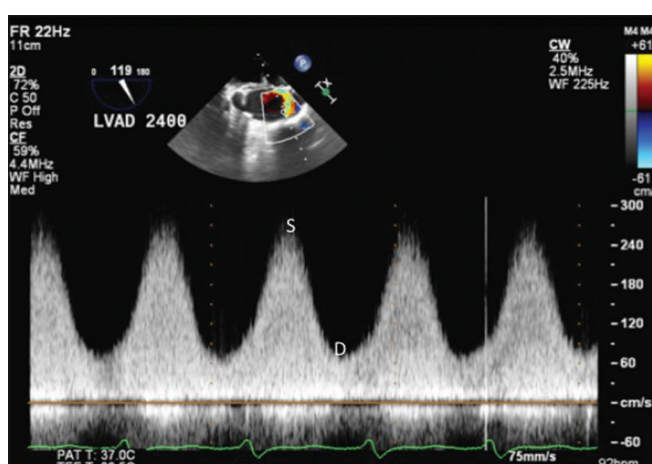


Figure 3: Spectral velocity pattern of the outflow cannula of HeartWare device showing systolic (S) and diastolic (D) flow

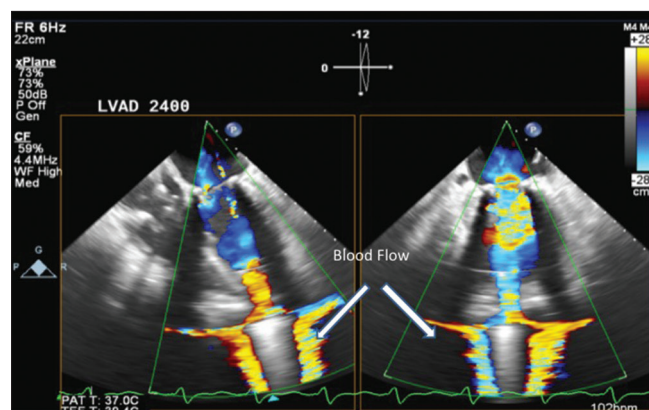


Figure 4: Mid-esophageal four-chamber view with inflow cannula of HeartWare device showing centrifugal color Doppler pattern within the device (arrows)

moves through the centrifugal pump chamber, it appears heterogeneous in appearance.

Discussion

Pump thrombosis following LVAD occurs in 2%–6% of cases. Such complications are partially linked with fluid dynamics of the continuous ventricular assist devices, such as hemolysis caused by excessive turbulence and clot formation incurred by regions of flow stagnation.^[2] HeartWare is the third-generation continuous flow LVAD and generates centrifugal pattern of blood flow. The device is designed to be placed intrapericardially with the impeller close to the inflow cannula. In the perioperative setting, interrogating the HeartWare devices is very difficult due to the interference of the Doppler by the impeller frequency and generation of the waterfall artifact. Meaningful images can be obtained by excluding the inflow cannula from the imaging sector and by manipulating the sector orientation. Our knowledge of ventricular flow pattern generated by these devices is limited to contrast imaging and flow dynamic studies using MRI outside the perioperative settings. There is one previously published case report of a

similar color flow pattern using color flow Doppler.^[3] There is a lot of interest recently on the intraventricular flow patterns generated in a normal as well as pathological heart.

Traditionally, color flow Doppler is used to measure axial flow velocities and abnormal turbulent flow.^[4] Techniques such as crossed-beam ultrasound and echo-dynamography, or vector flow mapping (VFM), has been proposed and used to assess blood flow. The technology of VFM is based on using color Doppler and thereby generating patterns of blood flow inside the heart chambers. Multiple research studies have demonstrated the usefulness of these velocity vectors patterns both *in vivo* and *in vitro* in detecting pathological blood flow states.^[5] More recently, speckle tracking has been used to assess blood flow in the left ventricular cavity.^[6] Technical advances in measuring velocity flow vectors have given us great insight in measuring intracardiac blood flow. Newer technologies like “transverse oscillations” can provide another tool to visualize and estimate blood flow. When these technologies can be superimposed on TEE, it will open up new doors for intraoperative cardiac blood flow imaging.^[7]

In these TEE images, we want to highlight the feasibility of using color Doppler to identify the centrifugal flow

pattern generated “within” the continuous flow third generation HeartWare device. Blood flow within the centrifugal HVAD chamber can theoretically be evaluated in the near future using color Doppler in patients with LVAD thrombosis. We wanted to highlight the fact that blood flow within the impeller device can be visualized with the use of color Doppler. In spite of the waterfall artifact that prevents any meaningful visualization of structures between the inflow cannula and the probe, the blood flow within the HVAD device can be seen and studied for future applications.

Currently, we do not have enough data to recognize this color flow pattern in a normal versus a thrombosed centrifugal third-generation device such as HVAD. Continued research in the analysis of these color flow patterns and their behavior in patients with thrombosis could open the doors for a new way to diagnose or predict impaired flow through these devices.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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